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PATENT

In re application of: BAILEY et al.

Attorney Docket No.:  
LAM1P126/P0562

Application No.: 09/536,347

Examiner: ALEJANDRO MULERO, L.

Filed: March 27, 2000

Group: 1763

Title: METHOD AND APPARATUS FOR  
PLASMA FORMING INNER MAGNETIC  
BUCKET TO CONTROL A VOLUME OF A  
PLASMA

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DECLARATION UNDER 37 CFR § 1.132Commissioner for Patents  
Washington, D.C. 20231

Sir:

I, Andrew D. Bailey III, declare as follows:

I am a co-inventor in the above-identified patent application.

I am a citizen of the United States of America. I am currently employed by Lam Research Corporation.

I received my BS in Applied Math, Engineering, and Physics from the University of Wisconsin, Madison in 1987 and my Ph.D. in Experimental Plasma Physics from the California Institute of Technology (Caltech) in Pasadena, CA in the year of 1993. I have been continuously engaged in academic and industrial plasma physics research and development since 1986. My work has been focused on semiconductor processing since my post-doc at AT&T Bell Labs, Murray Hill, NJ in 1993 and predominantly etch capital equipment process and hardware development since 1996.

I have reviewed U.S. Patent 5,370,765 to Dandl, U.S. Patent 5,464,499 to Moslehi et al., U.S. Patent 5,44,207 to Sekine et al., and U.S. Patent 5,302,205 to Hershkowitz et al. It would not be obvious to combine these references to obtain the invention as recited in claim 2, because the purpose and design of the magnetic arrangements in these patents are significantly different from our own patent. The designs of these magnetic arrangements are non-trivial and require careful consideration to meet the objectives of each particular embodiment.

Atty. Dkt. No. LAM1P126/P0562

Page 1 of 5

App. No. 09/536,347

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It is reasonably obvious for those generally skilled in the art to apply the concepts of putting magnets near where you want magnetic fields high and to attempt alternating pole arrangements to try to keep the magnetic field from penetrating some region away from the magnets. It is not a trivial matter even for those skilled in the art to combine the appropriate design elements to create a useful invention designed for a purpose as we disclose in our patent application. The patents cited show the lengths to which these non-trivial concerns drive inventors' design concepts. To those skilled in the art, one will notice in these patents certain magnetic design elements as necessary for their own stated purpose and other design elements that are novel either in combination with non-magnetic considerations such as relationship to the vacuum pumping arrangement, chamber wall material/plasma interaction desired, the plasma source being proposed or the usefulness for semiconductor processing.

Our invention does not represent an obvious cherry picking of simple building blocks from the cited or other references, but rather a complicated, inventive balance of design elements with creation of new concepts resulting beneficial achievement of stated goals. For instance, one might point to Hershkowitz and claim their fig 5 shows magnets inside a vacuum chamber and fig 3 shows magnets extending along the axis of a cylinder, so it might look easy to combine and have much of our claim 2. However, Hershkowitz's plasma source needs to confine the secondary electrons and so needs to have the magnets on the top and bottom of his designs as he shows. These are in fact non-trivial themselves since the substantial decrease in field strength inside the chamber is far less pronounced if you change his designs to make the magnets not completely encircled the plasma region. So the 'vertical' magnets in fig 3 are actually seen by one skilled in the art as hoops of magnets with their magnetic axes pointing 'into and out of' the proposed chamber volume. Our claim 2 magnetic arrangement with only the vertical magnets with radially directed magnetic axes is topologically different from the arrangements of Hershkowitz. For example, our arrangement has symmetry lacking in Hershkowitz designs that forces the field to be identically zero on the axis of the chamber and hence has a much stronger radial gradient in magnetic field and hence far less field at the wafer for comparable fields at the walls. This is advantageous itself, but additionally, the lack of top and bottom capping magnet arrays or hoop closures enables much enhanced substrate handling access and is more

Atty. Dkt. No. LAM1P126/P0562

Page 2 of 5

App. No. 09/536,347

appropriate for our self igniting and sustaining plasma source (as opposed to Hershkowitz's secondary electron capture requirement that wouldn't be well met with our design).

At the time leading up to our invention, I actually had to model and forcefully explain, to peers skilled in the art at our company, the subtle differences in field structure derived from hoop based magnetic designs even more general than Hershkowitz's designs, i.e., consider and reject hoop designs with magnetic poles not alternating, magnetic poles aligned on axis with the chamber either alternating or not in sign. These differences make such hoop designs inferior in forcing the magnetic field to be weak near the wafer. Hershkowitz's designs are ok for his application only if it has these full hoop enclosed or hoops capped with top and bottom arrays as shown in the patent.

Even if one were to say then that the concept of magnets in the vacuum from Hershkowitz was obviously combinable with one of the other cited patents, again to one skilled in the art, this is not clear since it overlooks that key elements were balanced in each design. Dandl's designs are similar to Hershkowitz in trying to put field all along the walls to help his ECR source work better. Dandl shows chamber walls with indentations to hold the magnets that are circumferentially oriented – again a hoop design aimed at a making a source work better. Dandl's figures also show no concern about enabling the magnetic design to prevent vacuum wall / plasma interactions or preventing deposition on the walls.

Moslehi's magnet arrangement looks more similar to ours, but is actually designed integrally with a system to get interactions between the wall and the plasma. That's actually opposite of our invention, where we are interested in reducing the effect of physical walls interacting with the plasma. Moslehi goes to lengths to describe the metal screen integrally mounted to the bottom of their chamber. Moslehi's design that most resembles ours is described as a magnetron permanent magnet assembly which further stresses the obvious linking of magnetron sputter concepts with using the magnetic field to encourage interaction with the walls.

With respect to work like Sakine, their concern is to actually generate and control a magnetic field across the wafer similar to a number of well known early plasma systems. These systems use the magnetic fields to move non-uniform plasmas around the wafer hence leading to a more uniform final result as long as the integrated effects of the non-uniform plasmas are more

uniform than the fixed system. The desire to put magnetic field across the wafer leads to the non-symmetric orientation of the magnetic axes of magnets placed physically around the chamber. To one skilled in the art this is clearly a very different magnetic system from ours, and the movement of the magnets is aimed at a specialized movement of the integrated magnetic field direction above the wafer. This is not the same as our invention which is again topologically different and designed with different purpose so that neither of our designs would work in the other's situation.

It would not be obvious to combine these references to obtain the invention as recited in claim 9 since none these references exploit the invention of using sleeves of pure material so that what small element of plasma wall interaction remains is with a specified material. Just showing magnets in a frame held in place or placing a screen between the plasma to protect the magnets or the wafer from undesired contamination is not the same as our invention. In the many years of many conversations with those skilled in the art, this sleeve concept has not come up in conversation except by myself and has always struck people as novel. In fact, the combination of the (at the time) recently readily available SiC tubes of sufficient length was the tipping point for me intellectually seeing this invention. This invention came together only after ~5 years of working around similar magnetic chambers, detailed modeling, plasma measurements, experience developing dielectric plasma etch applications (high density dielectric drift due to chamber wall depositions was still relatively recent realization) and chamber design. It was a singular sort of inventive event at the end of long struggle thinking of the problems – not an obvious extension or combination of things known to those skilled in the art.

I do not think our invention is obvious in light of these kinds of patents. There are just too many steps from these different concepts to our invention demonstrating the combination of creative magnetic field system design work coupled with the insight that vacuum chamber design can be included to create a new advantageous set of wall deposition and wall-plasma interactions without sacrificing vacuum pumping speed, wafer plasma processing symmetry or introducing

high fields on the wafer or sacrificing manufacturable wafer transport and plasma creation strategies.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both (under Section 1001 of Title 18 of the United States Code), and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.



Andrew D. Bailey III

12-09-04  
Date

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